1   DISK DRIVE COMPRISING AN ASYNCHRONOUS PARTITION LOCATED

2   ON A DISK BETWEEN TWO ISOCHRONOUS PARTITIONS

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4   **BACKGROUND OF THE INVENTION**

5   **Field of the Invention**

6   The present invention relates to disk drives. More particularly, the present invention

7   relates to a disk drive comprising an asynchronous partition located on a disk between two

8   isochronous partitions.

9   **Description of the Prior Art**

10   Disk drives may store both asynchronous and isochronous data. Asynchronous data is

11   transferred to and from the disk drive within a "best-effort" time interval, whereas isochronous

12   data is transferred to and from the disk drive within a "time-constrained" time interval. An

13   example of isochronous data is audio/video (AV) data transmitted from the disk drive to a

14   monitor for viewing. The AV data must be transmitted within a prescribed time interval in order

15   to avoid interruptions during the viewing session. An example of asynchronous data is user

16   application data, such as word processing documents, accounting documents, etc., manipulated by

17   an end user of a host computer. The transfer of asynchronous data to a host computer can be

18   interrupted (within some maximum time-out period) without significantly degrading the

19   performance of the host application.

20   Disk drives also typically employ error correction code (ECC) circuitry for correcting

21   errors on-the-fly in both the isochronous and asynchronous data. If the ECC circuitry is unable to

22   correct errors in asynchronous data, the disk drive typically performs various firmware retry

23   procedures in an attempt to correct the errors. The latency of the firmware retry procedures is

24   tolerated since it does not significantly degrade the performance of the host application while

25   ensuring the host application receives error-free data. If asynchronous data cannot be recovered

26   using the retry procedures, the disk drive responds with an error message rather than transfer bad

27   data to the host computer. In contrast, if the ECC circuitry is unable to correct errors in

1   isochronous data, the isochronous time constraints typically preclude using the firmware retry

2   procedures to correct the errors. This is not a significant problem since occasional errors in the

3   isochronous data do not significantly degrade the performance of the typical isochronous

4   application, such as streaming AV data to a monitor. Therefore the isochronous data, including

5   the errors, is typically transmitted by the disk drive to the host computer rather than respond with

6   an error message.

7   The disk within an isochronous/asynchronous disk drive is typically divided into an

8   isochronous partition for storing the isochronous data and an asynchronous partition for storing

9   the asynchronous data. An isochronous communication protocol, such as the AV/C protocol, is

10 used to access the isochronous partition according to the specified time constraints, and an

11 asynchronous communication protocol, such as the SBP-2 protocol, is used to access the

12 asynchronous partition in a best-effort manner. The asynchronous communication protocol may

13 also be used to access the isochronous data in a best-effort manner, for example, to edit a selected

14 portion of a video program.

15 It is desirable to support the concurrent (interleaved) transfer of both asynchronous and

16 isochronous data to and from the disk drive. If the isochronous and asynchronous partitions are

17 contiguous as illustrated in FIG. 1, the maximum seek distance may be from the inner diameter

18 track of the disk to the outer diameter track. If the disk drive is directed to make multiple

19 interleaved accesses to data located at the ends of the partitions, the cumulative seek times may

20 interfere with access to the time-constrained isochronous data. In addition, if the disk drive is

21 required to frequently seek between the asynchronous and isochronous data in order to satisfy

22 the isochronous time constraints, performance in accessing the asynchronous partition may

23 degrade.

24 There is, therefore, the need to ameliorate the inherent latency of seek times in a disk drive

25 which can interfere with the time-constrained access of isochronous data while concurrently

26 accessing asynchronous data.

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1 **SUMMARY OF THE INVENTION**

2 The present invention may be regarded as a disk drive comprising a disk having an

3 asynchronous partition and a first and second isochronous partition, wherein the asynchronous

4 partition is located between the first and second isochronous partitions in order to reduce the seek

5 time for the disk drive when seeking between the asynchronous and isochronous partitions. The

6 disk drive further comprises a head actuated radially over the disk, and a disk controller. The disk

7 controller is for writing data to and reading data from the first and second isochronous partitions

8 according to a time-constrained protocol, and is for writing data to and reading data from the

9 asynchronous partition according to a best-effort protocol.

10 In one embodiment, the time-constrained protocol employs the AV/C protocol, and the

11 best-effort protocol employs the SBP-2 protocol.

12 In one embodiment, the disk drive further comprises offset parameters for identifying the

13 beginning and end of the asynchronous partition. In one embodiment, the offset parameters

14 comprise a first parameter identifying the beginning of the asynchronous partition and a second

15 parameter identifying the end of the asynchronous partition. In another embodiment, the offset

16 parameters comprise a first parameter identifying the beginning of the asynchronous partition and

17 a second parameter identifying the size of the asynchronous partition.

18 In yet another embodiment, the disk comprises an AV file system for accessing the

19 isochronous data.

20 The present invention may also be regarded as a method of accessing a disk drive. The

21 disk drive comprises a disk and a head actuated radially over the disk. The disk comprises an

22 asynchronous partition and a first and second isochronous partition. The method comprises the

23 steps of using a time-constrained protocol to read isochronous data from at least one of the first

24 and second isochronous partitions, and using a best-effort protocol to read asynchronous data

25 from the asynchronous partition. The asynchronous partition is located on the disk between the

26 first and second isochronous partitions in order to reduce the seek time for the disk drive when

27 seeking between the asynchronous and isochronous partitions.

1   **BRIEF DESCRIPTION OF THE DRAWINGS**

2   FIG. 1 shows a prior art disk drive and the maximum seek distance between an

3   isochronous and asynchronous partition.

4   FIG. 2 shows a disk drive according to an embodiment of the present invention employing

5   a disk having an asynchronous partition located between two isochronous partitions which

6   reduces the maximum seek distance when seeking between the isochronous and asynchronous

7   partitions.

8   FIG. 3A illustrates the maximum seek distance when seeking between the isochronous and

9   asynchronous partition for the prior art disk drive of FIG. 1.

10   FIG. 3B illustrates the maximum seek distance when seeking between the isochronous and

11   asynchronous partitions for the disk drive of FIG. 2.

12   FIG. 4A illustrates the average random seek distance when seeking between the

13   isochronous and asynchronous partition for the prior art disk drive of FIG. 1.

14   FIG. 4B illustrates the average random seek distance when seeking between the

15   isochronous and asynchronous partitions for the disk drive of FIG. 2.

16   FIG. 5A illustrates the maximum seek distance when seeking between the ends of the

17   isochronous partition for the prior art disk drive of FIG. 1.

18   FIG. 5B illustrates the maximum seek distance when seeking between the ends of the

19   isochronous partitions for the disk drive of FIG. 2.

20   FIG. 6A illustrates the average random seek distance when seeking between two AV

21   streams stored in the isochronous partition for the prior art disk drive of FIG. 1.

22   FIG. 6B illustrates the average random seek distance when seeking between two AV

23   streams stored in different as well as the same isochronous partition for the disk drive of FIG. 2.

24   **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

25   FIG. 2 shows a disk drive 2 according to an embodiment of the present invention

26   comprising a disk 4 having an asynchronous partition 6 and a first and second isochronous

27   partition 8A and 8B, wherein the asynchronous partition 6 is located between the first and second

1   isochronous partitions 8A and 8B in order to reduce the seek time for the disk drive 2 when

2   seeking between the asynchronous 6 and isochronous partitions 8A and 8B. The disk drive 2

3   further comprises a head 10 actuated radially over the disk 4, and a disk controller 12. The disk

4   controller 12 is for writing data to and reading data from the first and second isochronous

5   partitions 8A and 8B according to a time-constrained protocol, and is for writing data to and

6   reading data from the asynchronous partition 6 according to a best-effort protocol.

7   In one embodiment, the disk drive 2 further comprises offset parameters 13 for identifying

8   the location of the asynchronous partition 6 with respect to the isochronous partitions 8A and 8B.

9   In one embodiment, the offset parameters 13 comprise a first parameter identifying the beginning

10   of the asynchronous partition 6 and a second parameter identifying the end of the asynchronous

11   partition 6. In another embodiment, the offset parameters 13 comprise a first parameter

12   identifying the beginning of the asynchronous partition 6 and a second parameter identifying the

13   size of the asynchronous partition 6.

14   Any suitable time-constrained and best-effort protocol may be employed. In one

15   embodiment, the time-constrained protocol employs the AV/C protocol, and the best-effort

16   protocol employs the SBP-2 protocol. The AV/C protocol is used to communicate with

17   audio/video equipment over an IEEE 1394 serial bus. The AV/C protocol uses the Function

18   Control Protocol (FCP) defined by IEC-61883, the ratified international standard for the transport

19   of audio/video command requests and responses. AV/C commands are transmitted through

20   AV/C transactions consisting of an AV/C command frame addressed to the target node's

21   FCP_Command register and zero or more AV/C response frames addressed to the requesting

22   node's FCP_Response register.

23   The AV/C Disk Subunit Enhancements for Hard Disk Drive Specification is a technical

24   specification of the 1394 Trade Association which includes enhancements to the AV/C protocol

25   for managing the storage and retrieval of audio/video (AV) data. Under this specification, AV

26   data is stored in the isochronous partitions 8A and 8B of the disk 4 in an AV track. An AV track

27   comprises a plurality of data sectors in one or both of the isochronous partitions 8A and 8B for

1   storing a stream of audio/video data. Each AV track is identified by a unique track ID in an entry

2   of an embedded AV file system stored on the disk 4. The entries in the AV file system are treated

3   as asynchronous data and accessed using a best-effort protocol to ensure the entries are

4   transmitted error-free to the host computer. In one embodiment, the entries of the AV file system

5   are duplicated to provide error correction redundancy.

6   The SBP-2 protocol for accessing the asynchronous partition employs Operation Request

7   Blocks (ORBs) which identify areas of the asynchronous partition 6 to read or write in terms of

8   Logical Block Addresses (LBAs). The disk controller 12 converts the LBAs into Physical Block

9   Addresses (PBAs) which identify physical sectors within the asynchronous partition 6. The LBA

10   to PBA addressing allows the disk drive 2 to "map-out" defective physical sectors using any

11   suitable defect mapping scheme.

12   FIG. 3A illustrates the maximum seek distance 14 when seeking between the isochronous

13   and asynchronous partition for the prior art disk drive of FIG. 1. In this example, the disk drive is

14   accessing an AV stream 16 at the extreme end of the isochronous partition, while concurrently

15   accessing (in an interleaved manner) asynchronous data 18 stored at the extreme end of the

16   asynchronous partition. Thus, the maximum seek distance 14 when seeking between the

17   isochronous and asynchronous data requires the entire stroke of the actuator arm. The associated

18   seek time may interfere with the time constraints of the isochronous data, particularly if the disk

19   drive performs multiple consecutive seeks to the end of the asynchronous partition. In addition,

20   the maximum seek distance 14 may degrade the performance in accessing the asynchronous data

21   18 if the disk drive is required to seek back and forth between the AV stream 16 in order to

22   satisfy the isochronous time constraints.

23   FIG. 3B illustrates how in the embodiment of FIG. 2 locating the asynchronous partition 6

24   between two isochronous partitions 8A and 8B significantly reduces the maximum seek distance

25   20A and 20B when seeking between the isochronous and asynchronous partitions. In one

26   embodiment, the isochronous partitions 8A and 8B are equal in size such that the maximum seek

27   distances 20A and 20B are equal in length. Also in the embodiment of FIG. 3B, the asynchronous

1   partition 6 is much smaller than the isochronous partitions 8A and 8B. Therefore the maximum

2   seek distances 20A and 20B are reduced in comparison to FIG. 3A to essentially one half the

3   stroke of the actuator arm (plus one-half the length of the asynchronous partition 6). This

4   reduction in seek distance and associated seek time improves performance by facilitating the time

5   constraints of the isochronous partitions 8A and 8B. It also improves performance with respect

6   to the asynchronous partition 6 by allowing more asynchronous data to be transferred to the host

7   computer before having to seek back to the isochronous partition to satisfy the isochronous time

8   constraints.

9   FIG. 4A illustrates the average random seek distance 22 when seeking between the

10   isochronous and asynchronous partition for the prior art disk drive of FIG. 1. On average, the

11   disk drive of FIG. 1 will access isochronous data 24 near the middle of the isochronous partition,

12   and access asynchronous data 26 near the middle of the asynchronous partition. Thus, the

13   average random seek distance 22 when seeking between isochronous and asynchronous data

14   requires one-half a stroke of the actuator arm.

15   FIG. 4B illustrates how in the embodiment of FIG. 2 locating the asynchronous partition 6

16   between two isochronous partitions 8A and 8B significantly reduces the average random seek

17   distance 28A and 28B when seeking between the isochronous and asynchronous partitions. In an

18   embodiment wherein the isochronous partitions 8A and 8B are equal and the asynchronous

19   partition 6 is significantly smaller than the isochronous partitions 8A and 8B, the average random

20   seek distance 28A and 28B is essentially reduced to only one-quarter a stroke of the actuator arm

21   (plus one-quarter the length of the asynchronous partition 6). This significant reduction in the

22   average random seek distance improves performance in satisfying the isochronous time

23   constraints and improves access to the asynchronous partition 6 by allowing more asynchronous

24   data to be transferred to the host computer before having to seek back to the isochronous

25   partition to satisfy the isochronous time constraints.

26   FIG. 5A illustrates the maximum seek distance 30 when seeking between the ends of the

27   isochronous partition for the prior art disk drive of FIG. 1. The maximum seek distance 30 when

1   concurrently accessing two AV streams 32A and 32B (in an interleaved manner) extends from

2   one end of the isochronous partition to the other end. FIG. 5B illustrates that the maximum seek

3   distance 34 for the disk drive of FIG. 2 when concurrently accessing two AV streams 36A and

4   36B. The maximum seek distance 34 extends through the asynchronous partition 6 from one end

5   of the first isochronous partition 8A to the other end of the second isochronous partition 8B

6   requiring the entire stroke of the actuator arm. In one embodiment, the size of the asynchronous

7   partition 6 is substantially smaller than the isochronous partitions 8A and 8B such that the

8   maximum seek distance is not significantly greater than the prior art of FIG. 5A. In an

9   embodiment wherein the size of the asynchronous partition 6 is significant, the AV streams are

10   stored in the isochronous partitions 8A and 8B to minimize the probability of concurrently

11   accessing two streams in separate partitions. For example, related AV streams likely to be

12   accessed together are stored in the same isochronous partition 8A or 8B so that the maximum

13   seek distance 38A or 38B does not extend through the asynchronous partition 6.

14   FIG. 6A illustrates the average random seek distance when seeking between two AV

15   streams stored in the isochronous partition for the prior art disk drive of FIG. 1. In the example

16   of FIG. 6A, the disk drive is seeking between an AV stream 40 located in the middle of the

17   isochronous partition, and an AV stream 42A or 42B located at an end of the isochronous

18   partition. The average random seek distance 44A or 44B equals one-half the length of the

19   isochronous partition. In an embodiment wherein the asynchronous partition is significantly

20   smaller than the isochronous partition, the average random seek distance 44A or 44B is essentially

21   one-half a stroke of the actuator arm.

22   FIG. 6B illustrates the average random seek distance when seeking between two AV

23   streams stored in separate as well as the same isochronous partition for the disk drive of FIG. 2.

24   When the AV streams 46A and 46B are stored in separate partitions, the average random seek

25   distance 48 equals one half a stroke of the actuator arm plus one-half the length of the

26   asynchronous partition 6. Thus, in an embodiment wherein the asynchronous partition 6 is

27   significantly smaller than the isochronous partitions 8A and 8B, the average random seek distance

1   48 is essentially the same as in FIG. 6A. When the AV streams are in the same partition (e.g., AV

2   streams 46A and 50), the average random seek distance 52 is reduced to one-half the length of the

3   isochronous partition 8A. In an embodiment wherein the isochronous partitions 8A and 8B are

4   equal and the size of the asynchronous partition 6 is significantly smaller than the isochronous

5   partitions 8A and 8B, the average random seek distance 52 is half the distance of the average

6   random seek distance 44A or 44B in FIG. 6A. In an embodiment wherein the size of the

7   asynchronous partition 6 is significant, the AV streams are stored in the isochronous partitions 8A

8   and 8B to minimize the probability of concurrently accessing two streams in separate partitions.